U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Lighting and Grid Integration Research

Pacific Northwest National Laboratory
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PNNL-SA-142494

Project Summary

Timeline

Start date: 10/1/2018 New Project

Planned end date: 9/30/2021

Key Milestones (FY 2019)

1. CLS grid services report 5/31/2019
2. CLS modeling report 8/31/2019

Key Partners

Technology Developers	
End users	
Electric Utilities	
Agencies, Power Authorities	NYSERDA

Budget

Total Project $ to Date:

- DOE: $500k
- Cost Share: $0

Total Project $:

- DOE: $1500k
- Cost Share: $0

Project Goals and Outcomes

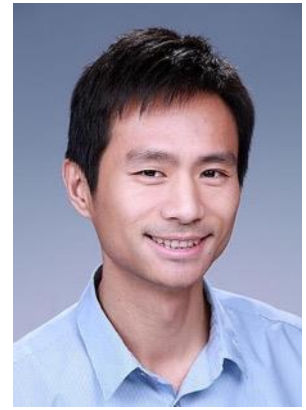
The ability of Connected Lighting Systems (CLS) to deliver potential grid services while simultaneously delivering sufficient lighting service and occupant satisfaction has not yet been proven or quantified. This project will quantify and advance the ability of CLS to provide grid services through modeling and simulation, laboratory testing, and field testing. Project results will be disseminated via targeted mechanisms to technology developers, lighting manufacturers, building owners and operators, system integrators, industry standards organizations, and other researchers.

Team

Michael Poplawski
EE/SS-Physics/PI
20/10 years

Michael Brambley
ME/Control/PI
28/22 years

Kelly Gordon
Public Policy/PM
30/19 years



Yan Chen
EE-AE/Mod-Sim
4/4 years

Michael Myer
LE/Codes-Standards
14/12 years

Peng Wang
EE-CS/Mod-Sim
1/1 years

Abhishek Somani
Economics/Grid
8/8 years

David Anderson
Economics/Grid
28/24 years

Jianming Lian
EE/Control-Grid
10/8 years

Mallikarjuna Vallem
EE/Power-Grid
10/6 years

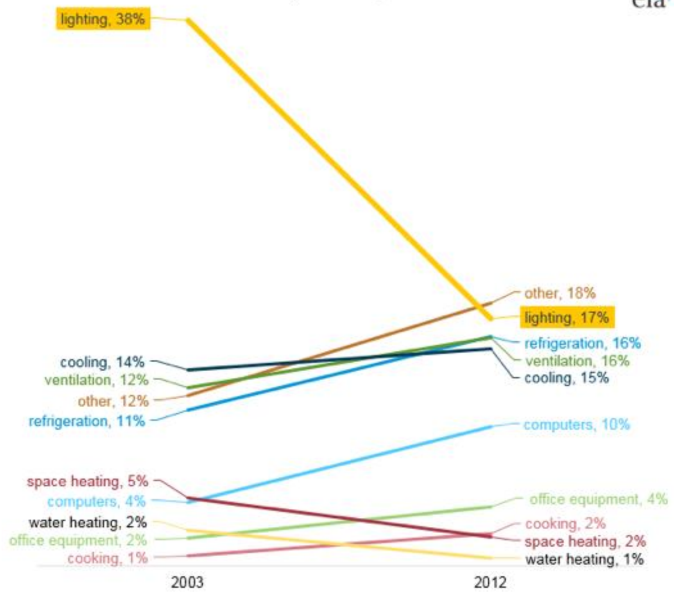
Challenge

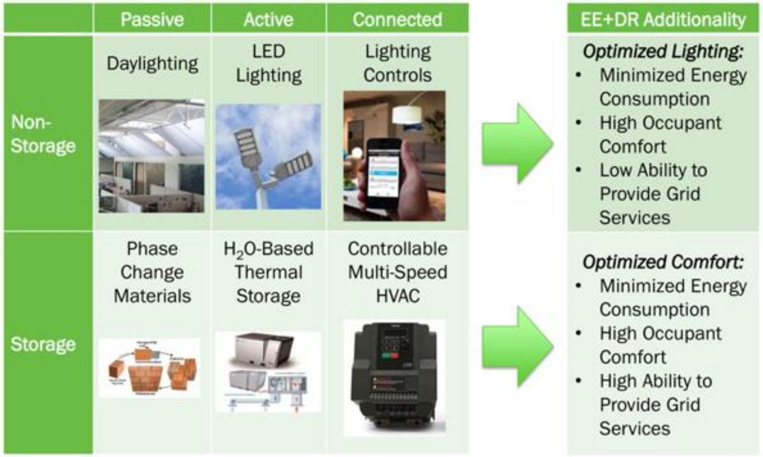
Connected Lighting Systems in GEBs have the potential to deliver improved lighting performance (energy, lighting quality, occupant satisfaction), improved performance of other (e.g., HVAC energy, security) building systems, other valuable data-enabled services, AND grid services. However, at this early stage in their development, their grid service potential is largely not being pursued for many reasons. At or near the top of this list are two key challenges:

1) Lighting systems have not received as much attention from lighting and grid service stakeholders to date as their HVAC counterparts due to perceived limitations. While their portion of building energy consumption is also significant, they typically cannot shift their consumption, and maintaining occupant satisfaction is more dependent on a variety of building and occupant factors.

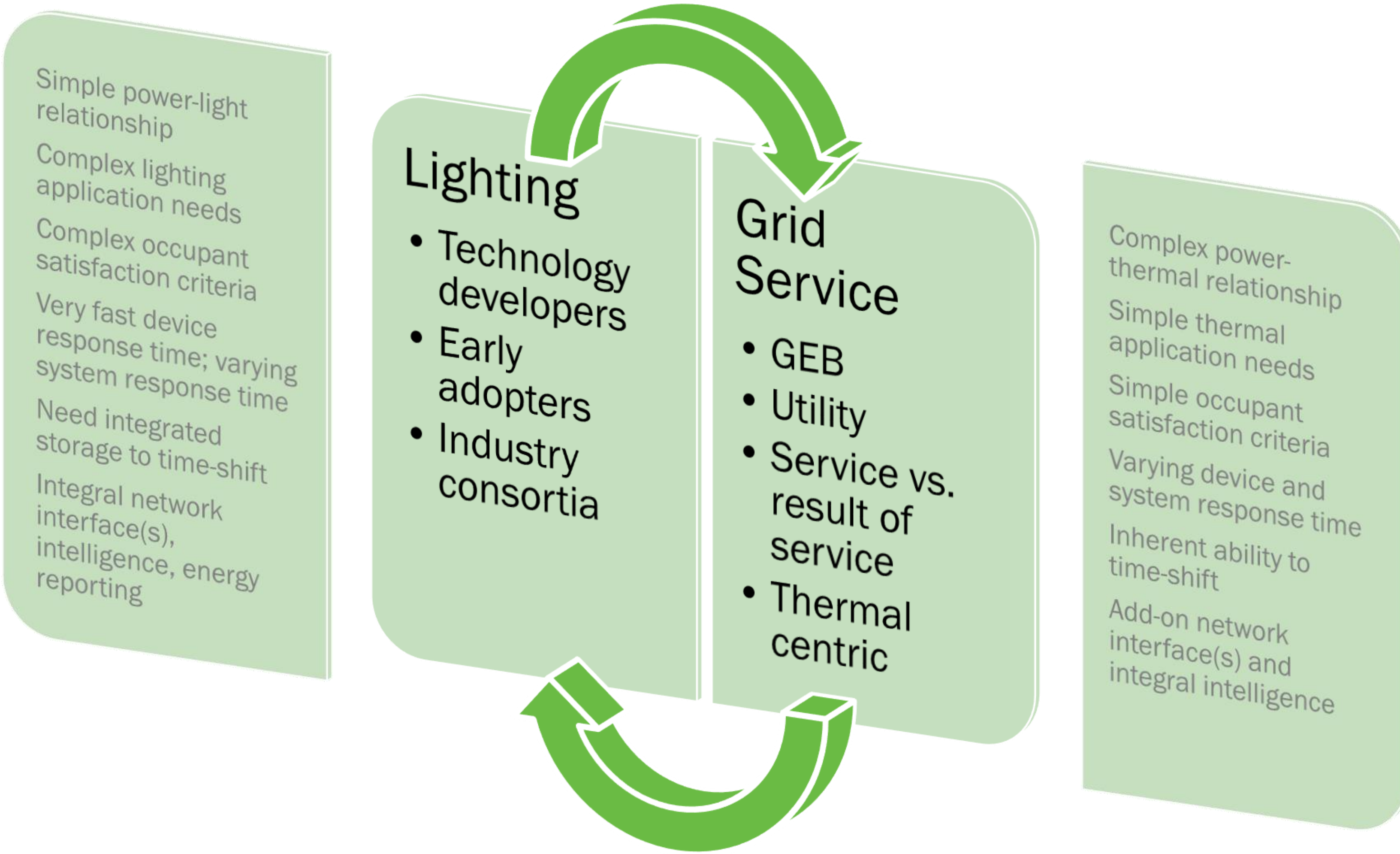
2) While the financial benefits for GEBs participating in the nascent grid service market are still very much unknown, much uncertainty exists as to whether lighting systems could, even theoretically, provide significant or unique grid services.

Figure 4: In the commercial sector, lighting is no longer the largest end use as a share of total electricity consumption



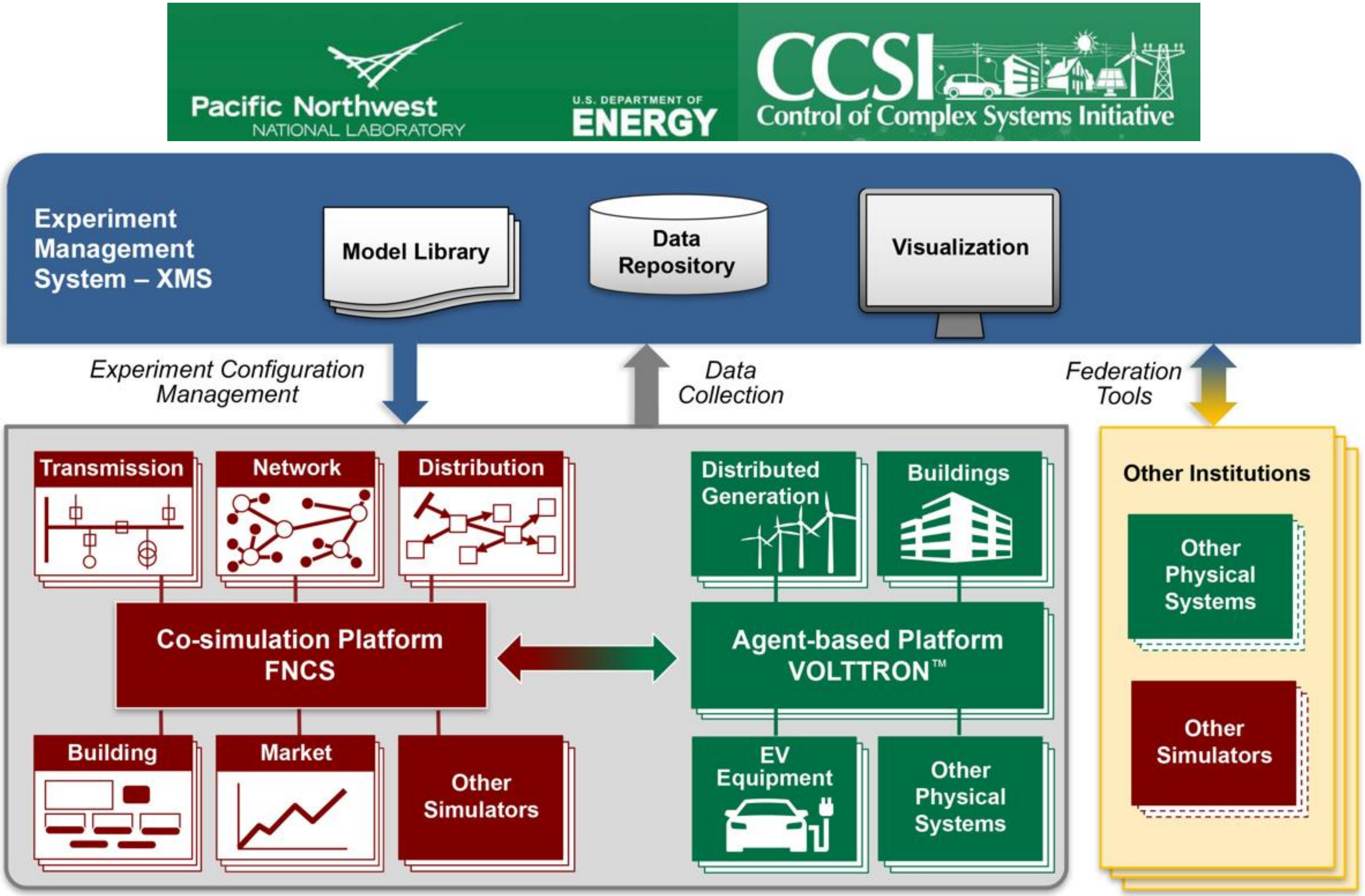


Approach – Cross stakeholder education



Goal: Define CLS characteristics that enable grid services, performance metrics key to the delivery of specific services, and methods for quantifying services.

Approach – Simulation based analysis

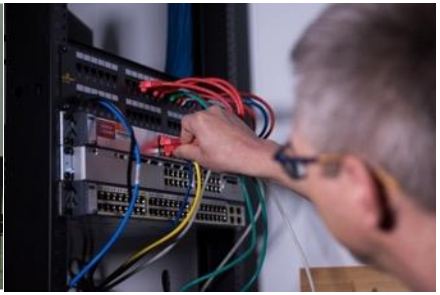


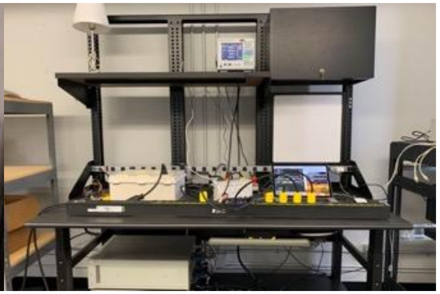
Goal: Quantify the potential for CLS to provide substantial or novel grid services under a range of building and electric grid operating conditions.

Approach – Laboratory & virtual test beds

Connected Lighting Test Bed





Early Adopter Deployment(s)

- **Goal: Develop field evaluation plan**
  - Project criteria and, if possible, potential project sites (not pilot studies)
  - Validate laboratory results
  - Characterize stakeholder (owner, operator, occupant, other) satisfaction
- **Goal: Initiate field evaluation, if suitable site identified**

Impact – Technology development

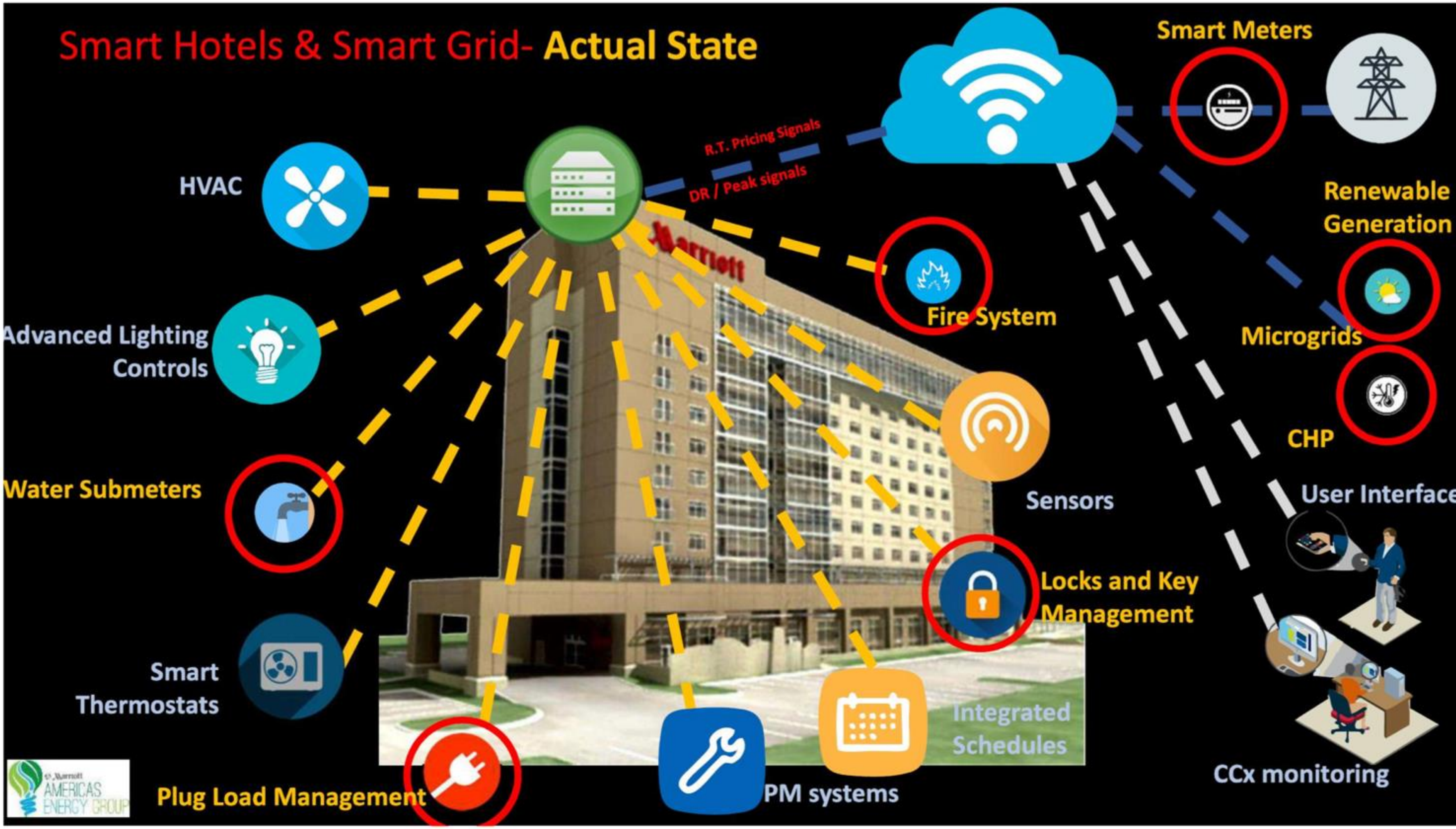
Near term

- CLS configurable for providing grid services
    - Grid service type
    - Occupant satisfaction sensitivity
- CLS capable of receiving and interpreting grid service signal
    - API
    - OpenADR, other protocols
- CLS capable of verifying delivery of grid service
    - Energy reporting
    - Accuracy, resolution, latency

Future term

- CLS with incremental ability to provide grid services via integration of incremental/modular storage
- CLS capable of real-time discernment of occupant satisfaction
    - Current, predictive occupancy
    - Current, predictive task
- CLC capable of incorporating specific occupant needs/preferences into grid-service capability
    - Configurable, occupant opt-in
    - Cybersecurity and privacy

Impact – Early adopter success



Source: Douglas Rath, Marriott International

Impact – Industry consensus

Near term

- Substantial/unique grid service capabilities of CLS
  - Focus for CLS technology developers
  - Design focus for GEB system integrators
- Grid service signaling interoperability with CLS
  - Applicable API resources
  - OpenAPI Initiative or other

Future term

- Substantial/unique grid service capabilities of storage-enabled CLS
- Grid service signaling interoperability with CLS
  - Embedded protocol support
  - OpenADR or other

Progress – Project coordination

CLS types

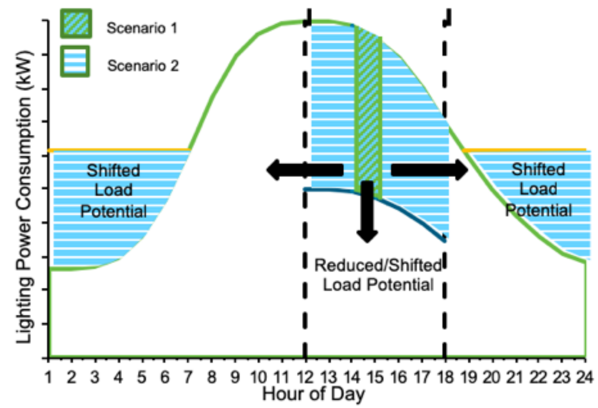
~~Advanced~~ Adaptive Lighting Control Algorithms

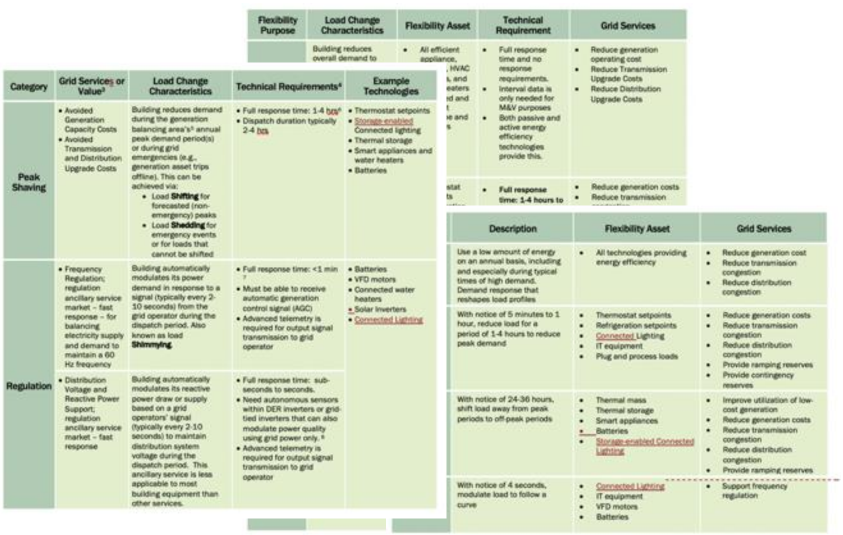
Integrated Batteries

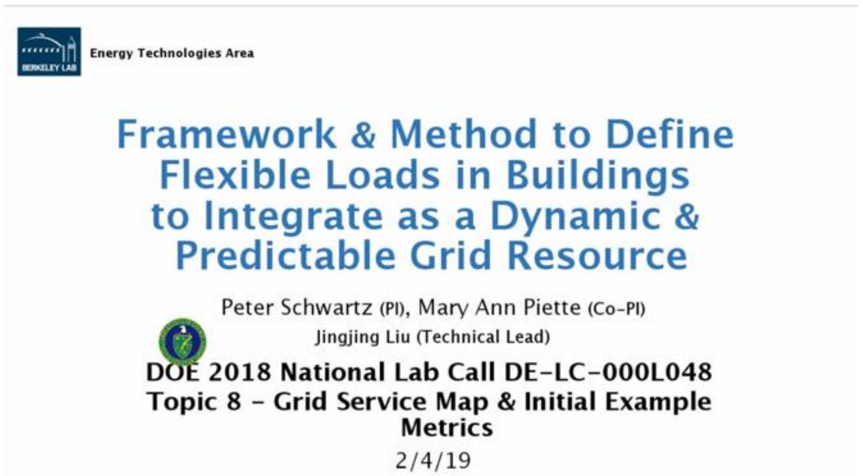
DC ~~LEDs~~ Luminaires

Hybrid Sunlight LED Systems

SSL Displays







Progress – Consensus grid services

GEB framework (draft)

1. Reduce generation operating costs
2. Reduce generation capacity costs
3. Provide contingency reserves (non-spinning)
4. Provide distribution voltage support
5. Provide frequency regulation
6. (Provide ramping)
7. Reduce transmission upgrade costs
8. Reduce distribution upgrade costs

Project proposal (Focused on limited set)

1. Energy service
2. Peak demand limiting
3. Regulation
4. Frequency response

PNNL cross-project analysis (in-progress)

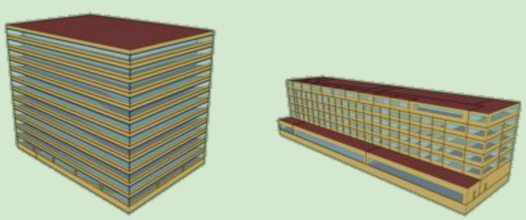
1. Long-term Capacity or Resource Adequacy
2. Regulation Up/Down
3. Operating Reserve
   a) Spinning
   b) Non-spinning
4. Other Market Products and Services
   a) Flexible Ramping
   b) Voltage Support
   c) Fast Frequency and primary frequency response
   d) Black Start
   e) Distributed system services

Progress – Lighting model parameters

Lighting profile (Space types)

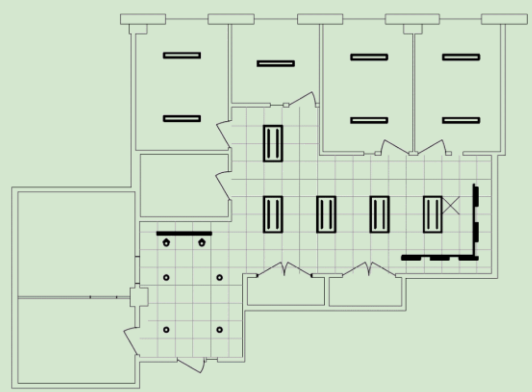
DOE commercial prototype building models

- Small, Medium, Large Office
- Standalone Retail
- Strip Mall
- Primary, Secondary School
- Outpatient Healthcare, Hospital
- Small, Large Hotel
- Warehouse
- Quick-service, Full-service Restaurant
- Mid-rise, High-rise Apartment



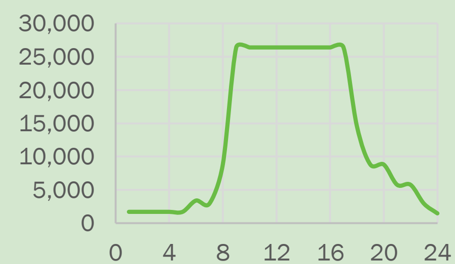
Lighting load (Power)

- ASHRAE 90.1-2019 lighting power density (LPD) values
- Up to four luminaire types per space
- ASHRAE 90.1 Lighting Subcommittee luminaire type power data



Lighting schedule (Hours-of-use)

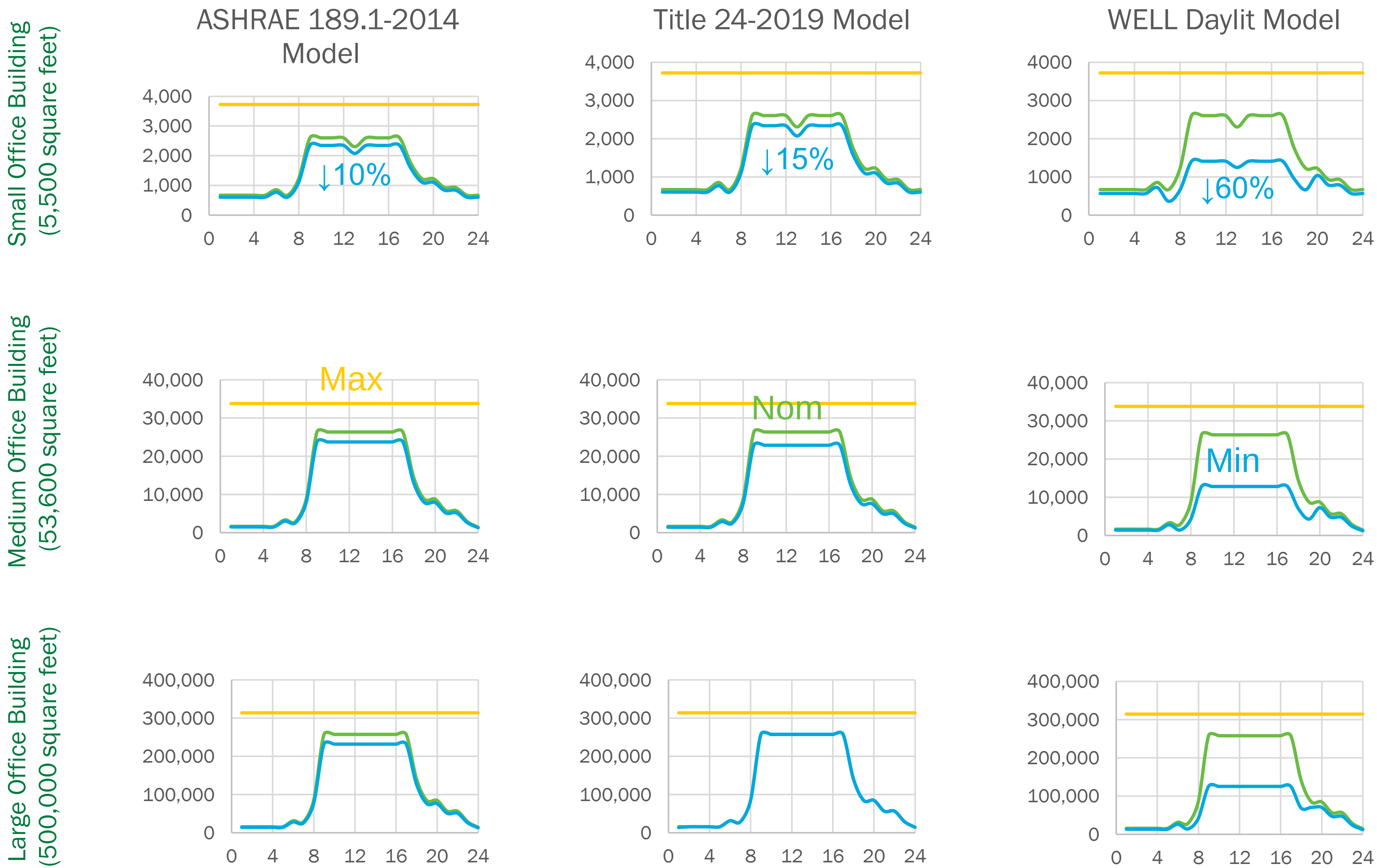
- ASHRAE 90.1-2009 Advanced Energy Design Guides, Technical Support Documents
- ASHRAE 90.1-2004 User's Manual Section G
- ASHRAE 90.1-1989 Section 13 Energy Cost Budget Method
- Apartment study (Gowri 2007)



Progress – Lighting model parameters

- Nominal illumination (power, per hour of day)
- Maximum illumination (power, per hour of day)
- Minimum illumination (power, per hour of day)
- Illumination (power) ramping (up/down) rate
- Delay (grid service signal → onset of service)
- ~~Response time (initiation of service → full activation of service)~~
- ~~Duration of service~~

Progress – Lighting parameters



Stakeholder Engagement – PAG (Project Advisory Group)

- Approximately six representatives
  - External stakeholders from the lighting, building, and electric-grid industries with the knowledge and background that enable them to judge market relevance of the project work
  - Assess the marketplace relevance of the project work, and make recommendations for increasing the market relevance
- Quarterly teleconference meetings
  - Updates on current project activities and approaches, preliminary research findings, upcoming planned activities, and summaries of other stakeholder interactions (e.g., webinars, presentations, reviewer feedback on papers)
  - DOE management invited
- Yearly DOE briefings
  - Summarizes teleconference meetings and the anticipated market relevance of the research as of that time
  - Include notable feedback from stakeholders responding to presentations, research reports, journal articles, and other outreach activities

Stakeholder Engagement – PAG recruitment

Technology developers (TBD): Lighting, Storage, Other?

End users (TBD)

Electric utilities (TBD): Large/typical, forward-looking, medium/small, municipal, cooperative

Electric utility agencies

Power Authorities (TBD)

Remaining Project Work – Work Plan

Task	Description	Due Date
1	Characterize CLS Opportunity for Providing Grid Services	M01-M6
2	Develop CLS Models and Integrate into Existing Co-Simulation Platform	M06-M12
3	Quantify CLS Potential Contributions to Grid Services Using Simulations 1) Prepare the co-simulation environment 2) Develop Simulation Test Plans 3) Perform Simulations and Analyze Results	M06-M30
4	Evaluate CLS Ability to Provide Grid Services in a Laboratory Environment	M06-M30
5	Develop Plans for Field Evaluation of CLS Ability to Provide Grid Services	M30-M36
6	Externally Validate Marketplace Relevance	M01-M36

Remaining Project Work – Key Milestones

	Task	Description	Due Date
FY19	1	Complete report characterizing CLS opportunity to provide grid services	3/2019
	2	Complete report on CLS models, integration into co-simulation platform	8/2019
	6	Complete DOE briefing on external validation of marketplace relevance	9/2019
FY20	3	Complete report on grid services provided only by CLS based on building-grid simulation results	3/2020
	3	Complete report on grid services provided by coordinated CLS and HVAC based on building-grid simulation results	8/2020
	6	Complete DOE briefing on external validation of marketplace relevance	9/2020
FY21	3	Complete report on grid services provided by coordinated CLS, storage-enabled CLS, and HVAC based on building-grid simulation results	2/2021
	4	Complete report on laboratory testing results	5/2021
	5	Complete report on field-testing plan	8/2021
	6	Complete DOE briefing on external validation of marketplace relevance	9/2021

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: New project starting in FY 2019.
Variances: Lower than anticipated spending in first half of FY; will increase in Q3 and Q4 FY19
Cost to Date: as of March 2019 month end: $62k cumulative cost to date
Additional Funding: None

Budget History					
FY 2018 (past)		FY 2019 (current)		FY 2020 – FY 2021 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
N/A	None	$500k	$0k	$1000k	TBD

Project Plan and Schedule

Project Schedule												
Project Start: 10/1/2018	Completed Work											
Projected End: 9/30/2021	Active Task (in progress work)											
	Milestone/Deliverable (Originally planned) use for missed											
	Milestone/Deliverable (Actual) use when met on time											
	FY19				FY20				FY21			
Characterization of Connected Lighting Systems Potential to Provide Grid Services	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Characterizing CLS opportunity to provide grid services - report outline in slide form												
Characterizing CLS opportunity to provide grid services - complete report												
Current/Future Work												
Complete report on CLS models, integration into co-simulation platform												
Complete DOE briefing on external validation of marketplace relevance												
Complete report on grid services provided only by CLS based on building-grid simulation results												
Complete report on grid services provided by coordinated CLS and HVAC based on building-grid simulation results												
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Complete report on grid services provided by coordinated CLS, storage-enabled CLS, and HVAC based on building-grid simulation results												
Complete report on laboratory testing results												
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